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Prediction of yield and optimum fishing effort for the Nile perch (*Lates niloticus)* stock of Lake Chamo, Ethiopia

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Abstract
Nile perch *(Lates niloticus)* is the major commercially exploited species in Lake Chamo that contributes more than 25% of the total annual landings from Lake Chamo. On the other hand, its potential is not rigorously studied so far in Lake Chamo and in the other lakes as well. In the present study, the Schaefer and Fox models were used to predict the Maximum Sustainable yield (MSY) and fishing effort maximum sustainable yield (fMSY) of Nile perch in Lake Chamo using catch effort data collected over a period of 5years (2011-2015). The MSY of Nile perch in Lake Chamo is about 450 tonnes/year and the optimum level of fishing effort to be expanded on the stock should be below 657 gill nets per day. The current yield estimate is almost three times less than that of the yield predicted during the early 1990's, which is 1125 tonnes/year. This shows that the Nile perch stock of Lake Chamo is overfished. Therefore, seasonal closure and enforcement of minimum mesh-size regulations as well as a limitation of the number of gillnets should be implemented on the Lake in order to protect the stock from depletion.

Keywords: Lates *niloticus*, Lake Chamo, stock assessment, Schaefer-Fox models, maximum sustainable yield, fishing effort maximum sustainable yield.

1. Introduction
Ethiopia has remarkable diversity of lakes which differ considerable in size, shape, depth permanency stratification and biotic diversity. The country has about 7,444 km^2 of inland waters (Abebe and Geheb, 2003) [1] from which about 51,481 tonnes of fish can be sustainably harvested per annum. However, the current level of fish production, which is around 10,000 tonnes/year (LFDP, 1997) [6], is below 1/5th of the potential. The riverine fishery in Ethiopia is still untapped so most of the Fish catch is to be expected from the main rivers. On the other hand, the commercial fishery of most Ethiopian lakes has tremendously increased to the extent that some commercially important fish species have already become victims of overexploitation.
Lake Chamo is one of the most overexploited lakes in the country. In this lake, fishing efforts have increased by five folds and landings by nearly ten folds since the last three decades. For example during the early 1980's the fishing efforts in the case of Nile perch were below 50 nets per day, where as in the 1990's, it had increased to about 110 nets per day (LFDP,1993) [4]. and currently more than 657 nets are set per day to exploit the Nile perch stock.
The impact of this alarming rate of fishing pressure is further worsened by the progressively decreasing trend of the mesh width of the nets. Also the exploitation of fish species of Lake Chamo is highly biased towards Nile perch.
The recommended minimum Nile perch gill nets mesh size by Lake fisheries development project is 28 to 35cm (LFDP, 1994) [5]. and now most Nile perch gillnets mesh size is 18cm. Illegal fishing practices in Lake Chamo are use of gillnets for chase and trap fish by beating the water after setting the net, operating the gillnets as seine net and dragging in the shallow fishing areas, sweeping the ground and indiscriminately collecting juveniles as well.
In view of this alarming rate of fishing pressure, there is an urgent need to set up sound management practices and this requires knowledge about the exploitation potentials of the stocks mainly Nile perch. The present work is therefore an attempt to estimate the maximum sustainable yield (MSY) of Nile perch in Lake Chamo as well as the optimum level of fishing efforts to be expanded on the Nile perch stock of the lake. Accordingly, catch and effort data

Collected over a period of 5 years (2011-2015) have been used to predict the exploitable potentials of the stock.

2. Materials and methods

2.1 Description of the study area and fishery

Lake Chamo is situated at $5^{0}40'$N, $37^{0}37'$E at an altitude of 1282m (Figure 1). It has surface area of 350 km^2. Its maximum depth is 13 m. The distance to Addis Ababa is 510 km. The shortest distance from Arbaminch is 10 km. The dominant vegetation on its shores constituted of paprus and *ambach* trees In Lake Chamo the most economically important fish species are Nile perch *(Lates niloticus*), Tilapia *(Oreochromi sniloticus*), Bagrus (*Bagrus docmak*) and African catfish (*Clarias garipenus)*. At least ten more fish species are found in the lake.

The fishery on lake Chamo is almost exclusively conducted with surface gillnet although long –lines are also used to some extent to catch Catfish. The nets are prepared locally by fishermen themselves or by some other people involved in fishing gear making.

The gill nets are the most important fishing gears and are typically set in the afternoon and checked early in the morning. They are removed only to change the fishing ground or when maintenance is necessary. Nile perch is used to be the major target species. However, because of low catch rates the fishing effort is shifting to Tilapia.

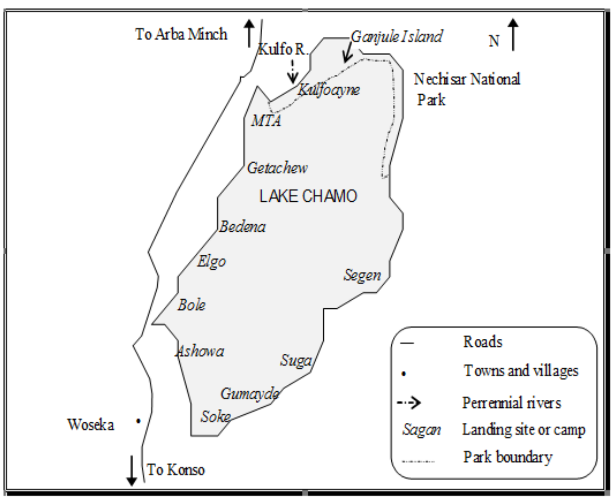


Fig 1: The map of Lake Chamo in the Ethiopian part of the eastern great Rift valley of Africa

2.2 Methods of data collection and analysis

The Nile perch catch and effort data were collected from 20 randomly sampled boats for five days per month at five major landing sites (4 sampled boats in each landing site). Spring balance was used to take the total weight of the catch of each sampled boat. The gillnets of each sampled boat were counted during every sampling occasion. Similarly, a gillnet inventory of all boats was done every month. Catch per Unit Effort (CPUE) was obtained by dividing sample catch by sample effort. Total catch was obtained by multiplying the average CPUE of the month by the total effort (number of nets set) and number of working days per month. Accordingly, the annual catch and effort of the respective year was obtained by summing up the monthly total catch and effort data. The Maximum Sustainable Yield (MSY) of Nile perch was estimated using Schaefer and Fox models as follows (Schaefer, 1954, 1957, Fox 1970) [10, 11, 3].

Schaefer parabola yield model: $Yi=afi+bfi^2$

Fox parabola yield model: $Yi=fi * e^{a+bfi}$

Where,

Yi = The total annual yield of Nile perch during year i (tonnes/year)

fi= The total annual effort expanded by the fishery during year i (no of gill nets/year)

a and b are constants of the relationship

The above parabola yield equations were transformed into linear form
as follows

Schaefer Linearized equation: $Yi/fi=a+bfi$

Fox linearized equation: $Ln(Yi/fi)=a+bfi$

Where,

Yi/fi = Catch per unit effort (tons/net) of the respective year

fi= The total annual effort expanded by the fishery during year i (No. of gill nets/year)

a and b are constants of the relationship

Accordingly a linear regression was established between Yi/fi and fi (Schaefer model) and between Ln(Yi/fi) and fi (Fox model) and the corresponding intercept (a) and slope (b)values were estimated. Hence, from the above relationship the maximum Sustainable yield (MSY) and optimum fishing effort level that gives the maximum sustainable yield(fMSY)were estimated as follows (Schaefer, 1954, 1957; Fox, 1970; Ricker, 1975; Caddy, 1980; Pauly, 1984; Schnute,1985) [10, 11, 3, 9, 2, 7, 12].

Schaefer model

$MSY = a^2/4b$

$fMSY= a/2b$

Fox model

$MSY = -(1/b) * e^{(a-1)}$

$fMSY= -1/b$

Where,

MSY is the maximum sustainable yield of Nile perch (tones/year)and fMSY is the fishing effort that should be expanded on the Nile perch stock per year to get the maximum sustainable yield(gill nets/ year).

3. Results and discussion

Annual Nile perch yield and effort level expanded by the fishery

Total annual yield of Nile perch (tones/year) and annual effort (number of gill nets per year) expanded on the Nile perch fishery of Lake Chamo between the years 2011 up to 2015 are shown in Table 1. Accordingly, on average an estimated number of 228855 gill nets were expanded by the fishery annually during the mentioned five years and this gave an average of about 391.4 tonnes of Nile perch per year. This means an average of about 627nets were set per day during the said period. The number of gillnets given in the table from 2011-2015 shows that there is fishing pressure in Nile perch fishery on lake Chamo.

Table 1: Total annual effort (gillnets/year) and annual yield (tonnes/year) of Nile perch caught from Lake Chamo between 2011 and 2015. CPUE and Ln (CPUE) values prepared for Schaefer and Fox yield model, respectively.

Year	Total annual effort (nets/year)	Total annual yield (tones/year)	CPUE	LN CPUE
2011	108770	250	0.002298	-6.075529922
2012	168265	380	0.002258	-6.093124144
2013	209510	450	0.002148	-6.143279167
2014	271195	480	0.00177	-6.336807294
2015	386535	397	0.001027	-6.881041418
Average	228855	391.4		

3.1 Yield estimation

Based on the Schaefer model, the equation that expresses the CPUE (Yi/fi) of Nile perch in Lake Chamo as a function of fishing effort is given as follows (Figure 2a).

Yi/fi = 0.003 -0.000000005*fi

From this, the corresponding parabola yield equation for the Nile perch of the Lake Chamo fishery is expressed as follows (Figure 3a)

Yi = 0.003fi – 0.000000005fi^2

Accordingly, values of the intercept (a) and the slope (b) are

.

Similarly, the linearized as well as the parabola yield equation for the Nile perch of Lake Chamo based on the Fox model are expressed as follows.

Ln(Yi/fi) = -5.617 – 0.000003fi Linear form (Fig 2b)
Yi = fi *e-5.617– 0.000003fi Parabola form (Fig 3b)

From the above expression, values of the intercept (a) and the slope (b) are given as -5.617 and -0.000003, respectively. Hence, based on the above, the MSY and fMSY values are estimated as follows

Schaefer model MSY = 450 t/year, fMSY = 300000 **gill nets/year**
Fox model MSY = 445.8124**t/year, fMSY =** 300000**gill nets/year**

As shown above, both models gave the same fishing effort maximum sustainable yield (fMSY) for the Nile perch of Lake Chamo which is 300000 nets per year. Hence, on a daily basis an effort level of about 822 nets. The yield estimates obtained from both models is quite similar and this indicates that the estimates can be well trusted. In this case 450tonnes of Nile perch can be harvested sustainably from Lake Chamo but this figure is to be seen as a long term average. As per the recommendation of Sparre and Venema (1992) [13], safe level of exploitation (i.e., optimum fishing effort) is 20% less than the fishing effort that gives the maximum sustainable yield (fMSY). Taking 80% of the fMSY obtained in this study (822 nets /day), gives 657 gillnets /day, so the optimum level of fishing to be expanded on the Nile perch of Lake Chamo should not exceed 657 gillnets /day.

The yield estimates obtained in this study (450tonnes/year) is close to the safe level of exploitation recommended by Reyintijens Dirk and Tesfaye Wudineh (1998) [8], which is 465 tonnes/year.

The estimated optimum effort level in the present study for the Nile perch stock of Lake Chamo is close to 657 gillnets/day is higher than the recommended safe level of fishing estimated by. Reyintijens Dirk and Tesfaye Wudineh. (1998) [8] as 400 nets /day.

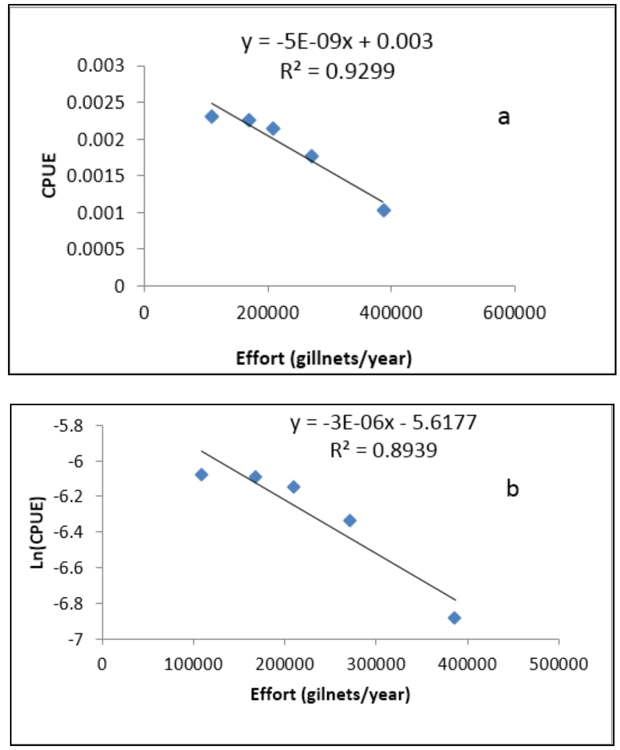
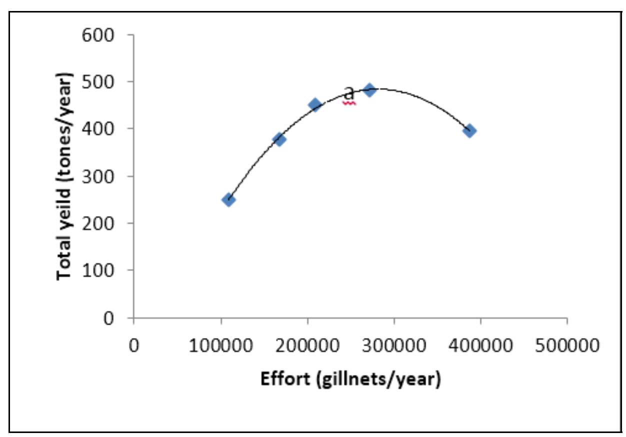


Fig 2: Yield per unit effort (tonnes/gillnet) of Nile perch caught from Lake Chamo between 2011 and 2015 (a) and Natural log values of Yield per unit effort (b) expressed as a function of total annual effort.



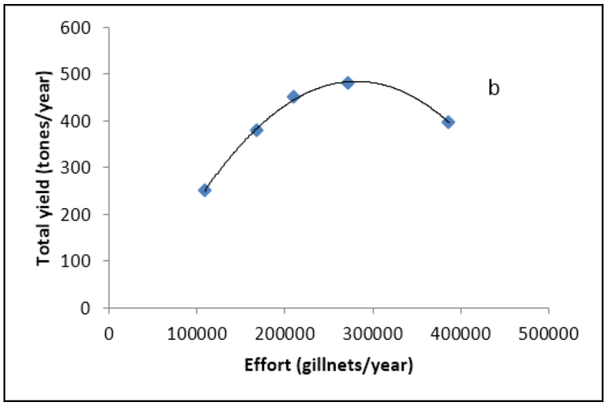


Fig 3: Total annual yield (tonnes/year) as a function of fishing effort for the Nile perch stock of Lake Chamo Schaefer (a) and Fox (b) parabola yield curves are fitted to the data and shown with the respective equation

4. Conclusion

The yield estimate obtained in the present study is three times less than that of the yield estimate of 1125 tonnes/year based on data collected between 1992-1994 (LFDP, 1994). This is because of huge increase in fishing effort and decrease in mesh size of the gillnets that happened since the last two decades. This shows that the Nile perch of Lake Chamo is being over fished. If this continues and enforcement measures are not taken promptly, the Nile perch of the Lake Chamo will be seriously depleted. To improve the current situation, it is therefore recommended to further reduce the number of the fishing gears (nets) as well as increase the mesh size of gillnets.

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